ENGLISH

TRANSLATION

OF INTERNATIONAL

APPLICATION AS FILED

DESCRIPTION

ANTENNA AND PORTABLE RADIO COMMUNICATION APPARATUS

Technical Field

The present invention relates to antennas and portable radio communication apparatuses, and more particularly, to an antenna that performs a multiple resonance and a portable radio communication apparatus including the antenna.

Background Art

Structures of antennas and portable radio communication apparatuses of this type are disclosed, for example, in Patent Documents 1 to 4.

In Patent Document 1, as shown in Fig. 15, a technology for increasing the bandwidth of a single-resonance 1/4 λ microstrip antenna 100 that is a so-called sheet metal inverted-F antenna is suggested. More specifically, the bandwidth is increased by providing an antenna element 105 and installing a linear ground wire 101a or a wound ground wire 101b at a corner or the like of a ground plate (ground electrode) 102. In addition, a narrower short-circuit wire 104 is provided independent of a feeding wire 103. The short-circuit wire 104 serves as a short-circuit stub functioning as a matching circuit for matching with an input impedance for feeding.

In addition, in Patent Document 2, as shown in Fig. 16, a technology for causing a first antenna element 202 and a second antenna element 203 to produce a double resonance by installing

the first antenna element 202 and the second antenna element 203 in a portion near an end 201 in a longitudinal direction (one of two shorter sides at both ends) of a casing 204 of a cellular phone unit 200 and by supplying power to the first antenna element 202 and supplying no power to the second antenna element 203 is suggested.

In addition, in Patent Document 3, as shown in Fig. 17, a surface-mount antenna main unit 300 in which a feeding radiation electrode 301, a first non-feeding radiation electrode 302, and a second non-feeding radiation electrode 303 produce a multiple resonance by disposing the feeding radiation electrode 301, the first non-feeding radiation electrode 302, and the second non-feeding radiation electrode 303 on a dielectric base member 304 is suggested. In the surface-mount antenna main unit 300, electric field coupling between a feeding radiation electrode and a non-feeding radiation electrode is achieved by causing the dielectric base member 304 to function as an electric capacitor connected to the non-feeding radiation electrodes 302 and 303. Accordingly, the surface-mount antenna main unit 300 realizes a multiple resonance.

In addition, in Patent Document 4, as shown in Fig. 18, a technology for improving antenna gain while maintaining the sharpness of the directivity of the whole antenna by forming a ground opening 402 in a ground electrode 401 on which a surface-mount antenna main unit 400 is provided, in addition to the invention described in Patent Document 3, is suggested. Since

the ground opening 402 is formed by drilling a through hole in the ground electrode 401, the ground opening 402 is surrounded by a conductor of the ground electrode 401. The whole antenna including the surface-mount antenna main unit 400 is a multiple-resonance antenna in which a radiation electrode 403 and a radiation electrode 404 are provided on a surface of a dielectric base member 402.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-283238

Patent Document 2: Japanese Unexamined Patent Application Publication No. 2003-283225

Patent Document 3: Japanese Unexamined Patent Application Publication No. 2003-8326

Patent Document 4: Japanese Unexamined Patent Application Publication No. 2003-347835

Disclosure of Invention

However, the foregoing portable radio communication apparatuses have problems described below.

In the technologies described in Patent Documents 1 and 2, it is difficult to achieve an excellent multiple resonance including two or more resonances in fundamental waves and harmonic waves.

That is, since the antenna elements 105, 202, and 203, and the ground wires 101a and 101b are not loaded with a dielectric substance, it is difficult to set electromagnetic coupling between these component parts in a desired manner. In addition,

since a position of the ground plate 102 to which the ground wires 101a and 101b are connected is restricted to a corner or the like of the ground plate 102, sufficient electromagnetic coupling may not be achieved between the ground wires 101a and 101b and the ground plate 102. Thus, for example, when a resonance is set so as to match one of a fundamental wave and a harmonic wave, it is often difficult to achieve matching of the resonance with the other one of the fundamental wave and the harmonic wave.

In addition, in particular, the ground wire 101a suggested in Patent Document 1 expands (extends) along a line from a longer side of the ground plate 102 to the outside. Thus, when an antenna including the ground wire 101a is incorporated into, for example, a cellular phone unit, the ground wire 101a protrudes in an elongated shape in a horizontal direction from the body of the cellular phone unit. Thus, the protruding ground wire 101a greatly disturbs users. In addition, handling of the whole cellular phone unit is complicated. When the wound ground wire 101b is provided, the ground wire 101b is less disturbing than the linear ground wire 101a. However, since the ground wire 101b greatly expands outside the ground plate 102, this arrangement is contrary to a reduction in the overall size of the cellular phone unit including the ground wire 101b.

In addition, it is difficult to achieve an increase in bandwidth (to achieve a wider bandwidth in which transmission and reception can be performed) while reducing the thickness

(lowering the profile) of the entire antenna. That is, as shown in Fig. 15, since coupling saturation caused by an electric field E that leaks out toward the ground wire 101b must be avoided, a certain distance must be provided between the ground plate 102 and the ground wire 101b. Thus, due to such a distance, a reduction in thickness and miniaturization are prevented. In addition, since a certain height (the height from the ground plate 102 to the antenna element 105) is required for a so-called inverted-F structure in order to achieve an increase in bandwidth, such a height prevents the reduction in thickness.

In addition, when the above-mentioned antenna is used for, for example, a cellular phone unit, a problem occurs in which the antenna characteristics are adversely affected when the user brings his or her head closer to the antenna for conversation. That is, since the above-mentioned antenna is not loaded with a dielectric substance, a large electric field leaks out toward the head. Thus, when the head, which has a high dielectric constant, approaches the antenna, a function to transmit and receive radio waves for communication that is the originally required function of an antenna may be inhibited.

In addition, since the ground wires 101a and 101b and the antenna elements 202 and 203 are connected to an end on one side of the ground plate 102, deviation occurs in the current distribution of the ground plate 102 in a direction along the one side of the ground plate 102, and an induced current is generated. Due to a voltage drop of the induced current, the electric field

that leaks out toward the head is increased. Thus, when a user brings his or her head closer to the antenna, the function to transmit and receive radio waves for communication that is the originally required function of the entire antenna is inhibited.

In addition, in particular, in the technology described in Patent Document 2, when the antenna elements 202 and 203 expand outside a ground plate (not shown in Fig. 16), an electrostatic shielding effect of the ground plate does not reach the antenna elements 202 and 203. In particular, when the antenna elements 202 and 203 are disposed in a portion near the upper end of a cellular phone unit, these elements become the closest to the head of a user when the user uses the cellular phone unit. Thus, when the head, which has a high dielectric constant, approaches the antenna, the operation characteristics of the entire antenna are adversely affected by the head. In addition, when the antenna elements 202 and 203 expand on the ground plate, an advantage of a wider bandwidth can be achieved due to a multiple resonance, compared with a single-resonance antenna. However, since the Q-value of each of two resonances constituting the multiple resonance is high, there is a limit to the increase in bandwidth.

In addition, in the technologies described in Patent Documents 1 and 2, the elongated ground wire 101a protruding at the corner of the ground plate 102, the antenna element 105 disposed with a predetermined height from the ground plate 102, and the like are obstructive to the attachment of a CCD image

pickup element, a flash element, a liquid crystal display element (not shown), or the like. Alternatively, the elongated ground wire 101a protruding at the corner of the ground plate 102, the antenna element 105 disposed with a predetermined height from the ground plate 102, and the like serve as constraints when designing the body of a radio communication apparatus, such as a cellular phone unit. This inhibits a reduction in the thickness and miniaturization of the entire radio communication apparatus.

In contrast, in the technology described in Patent Document 3, although a reduction in the thickness and miniaturization of the entire antenna and an increase in bandwidth can be realized together, a further increase in bandwidth is desired. Thus, meeting the need for this increase is requested.

In addition, in the technology described in Patent Document 4, due to the ground opening 402, the antenna gain can be improved while the sharpness of the directivity of the entire antenna is maintained. However, since the ground opening 402 is merely a space (opening) of limited size, such as, at most, about several millimeters, surrounded by the ground electrode 401, the ground opening 402 is not regarded as being an opening significantly large with respect to a wavelength, depending on the frequency band to be used. Thus, the desired increase in bandwidth cannot be achieved.

In order to solve the above-described problems, an object of the present invention is to provide an antenna that achieves a reduction in the thickness and miniaturization of the overall

size and that achieves a further increase in bandwidth and to provide a portable radio communication apparatus using such an antenna.

In order to achieve the above-mentioned object, an antenna according to an aspect of the present invention includes a substrate including a ground electrode of a substantially rectangular shape, a feeding radiation element including feeding means and including a radiation electrode inside or outside a dielectric substance, a first non-feeding radiation element electrically connected to the ground electrode and including a radiation electrode inside or outside a dielectric substance, and a second non-feeding radiation element electrically connected to the ground electrode and including a radiation electrode inside or outside a dielectric substance. The feeding radiation element is disposed on the ground electrode such that a face of the radiation electrode of the feeding radiation element is substantially parallel to a face of the ground electrode and such that the feeding radiation element is disposed in the vicinity of a predetermined side of four peripheral sides of the ground electrode. The first non-feeding radiation element is disposed on the ground electrode such that a face of the radiation electrode is substantially parallel to the face of the ground electrode and such that the first non-feeding radiation element is disposed next to the feeding radiation element so as to be in the vicinity of the predetermined side. The second non-feeding radiation element is disposed such that the second non-feeding

radiation element is adjacent to both the feeding radiation element and the first non-feeding radiation element and such that at least part of the second non-feeding radiation element projects outside the ground electrode from the predetermined side.

With this arrangement, the ground electrode, the feeding radiation element, the first non-feeding radiation element, and the second non-feeding radiation element produce a triple resonance with an excellent matching over a wide bandwidth.

In addition, since the radiation electrode of each of the feeding radiation element and the first and second non-feeding radiation elements is loaded with a dielectric substance, the amount of electric field coupling between the three electrodes can be set with high flexibility.

In addition, the feeding radiation element and the first non-feeding radiation element of the three electrode elements are disposed on the ground electrode, and the second non-feeding radiation element is disposed outside the ground electrode. Thus, the three electrode elements produce a multiple resonance constituted by three types of resonances that are clearly different from each other. Thus, for example, a multiple resonance with an excellent matching can be achieved over a wide band including, for example, a fundamental wave, a first harmonic wave, and a second harmonic wave. Thus, a further increase in bandwidth can be achieved.

In addition, the second non-feeding radiation element loaded with a dielectric substance is disposed outside the ground

electrode, instead of being disposed on the ground electrode. Thus, a ground wire and an antenna element disposed away from a ground plate with a certain distance (thickness) therebetween that are necessary for causing a known so-called inverted-F antenna to produce a multiple resonance are not required, and a reduction in the thickness and miniaturization can be achieved. In addition, since such a ground wire and the like are not required, restriction on the shape of a corner portion or the like of the ground electrode (ground plate) due to such a ground wire can be eliminated.

The second non-feeding radiation element may be electrically connected at substantially a central position of the predetermined side of the ground electrode.

With this arrangement, the second non-feeding radiation element is electrically connected at substantially a central position of one side of the ground electrode. Thus, induced currents flow symmetrically with respect to substantially the central position of the one side and have opposite phases, and the induced currents cancel each other. Thus, for example, leakage of an electric field from an antenna to a head of a user when the user brings his or her head closer to the antenna can be suppressed.

A resonance due to the second non-feeding radiation element may be assigned to a higher frequency side or a lower frequency side of a multiple resonance due to the feeding radiation element and the first non-feeding radiation element to produce a triple

resonance.

With this arrangement, a further increase in bandwidth and in efficiency can be achieved compared with a case of two resonances.

A resonance due to the second non-feeding radiation element may be assigned to a higher frequency side or a lower frequency side of a multiple resonance due to a harmonic wave of the feeding radiation element and a harmonic wave of the first non-feeding radiation element to produce a triple resonance.

With this arrangement, a further increase in bandwidth and in efficiency can be achieved compared with a case of two resonances.

The ground electrode may be formed of a conductor pattern that is provided on the substrate and that has a substantially rectangular shape when viewed in plan. The feeding radiation element and the first non-feeding radiation element are provided close to one of two shorter sides at ends in a longitudinal direction of the ground electrode. The second non-feeding radiation element is provided such that almost the entire second non-feeding radiation element projects outside the ground electrode from the side.

With this arrangement, the antenna is suitable for being incorporated into, for example, a cellular phone unit having an elongated body shape.

The radiation electrode of each of the feeding radiation element, the first non-feeding radiation element, and the second

non-feeding radiation element may be provided on a dielectric base member or within the dielectric base member.

With this arrangement, an antenna element in which the feeding radiation element, the first non-feeding radiation element, and the second non-feeding radiation element are integrated with a dielectric base member can be produced. Such an integrated antenna element can be easily provided on the ground electrode.

The feeding radiation element, the first non-feeding radiation element, and the second non-feeding radiation element may be formed by insert molding or outsert molding using, as the dielectric base member, a dielectric material with thermoplastic resin.

The radiation electrode of each of the feeding radiation element and the first non-feeding radiation element may be provided on a dielectric base member. The radiation electrode of the second non-feeding radiation element may be provided on a dielectric base member that is different from the dielectric base member on which the radiation electrode of each of the feeding radiation element and the first non-feeding radiation element is provided.

With this arrangement, the feeding radiation element and the first non-feeding radiation element can be provided on the ground electrode such that the feeding radiation element and the first non-feeding radiation element are integrated with each other. Then, the second non-feeding radiation element can be added to

the feeding radiation element and the first non-feeding radiation element that are integrated with each other.

The feeding radiation element and the first non-feeding radiation element may be formed by insert molding or outsert molding using, as the dielectric base member, a dielectric material with thermoplastic resin. The second non-feeding radiation element may be formed by insert molding or outsert molding using, as the different dielectric base member, a dielectric material with thermoplastic resin.

The dielectric base member and the different dielectric base member have a fitting structure in which a fitting state is uniquely defined by fitting the dielectric base member to the different dielectric base member.

At least one of a chip capacitor and a chip inductor may be installed in the middle of at least one of an electrical connection path between the radiation electrode and the ground electrode, an electrical connection path between the radiation electrode of the first non-feeding radiation element and the ground electrode, and an electrical connection path between the radiation electrode of the second non-feeding radiation element and the ground electrode.

A portable radio communication apparatus according to an aspect of the present invention includes any one of the above-mentioned antennas.

As described above, according to the present invention, each of the feeding radiation element, the first non-feeding radiation

element, and the second non-feeding radiation element is loaded with a dielectric substance and disposed on the ground electrode, and the second non-feeding radiation element projects outside from one side of the ground electrode. Thus, an antenna that achieves a reduction in the thickness and miniaturization of the overall size and that achieves a further increase in bandwidth can be provided.

In addition, according to the present invention, a portable radio communication apparatus that achieves excellent communication in a wide band and that achieves a reduction in the thickness and miniaturization can be provided.

Brief Description of the Drawings

[Fig. 1] Fig. 1 is a plan view of an antenna according to a first embodiment of the present invention.

[Fig. 2] Fig. 2 is a side view of the antenna according to the first embodiment of the present invention.

[Fig. 3] Fig. 3 is a perspective view of the antenna according to the first embodiment of the present invention.

[Fig. 4] Fig. 4 is a perspective view of a second non-feeding radiation element 5.

[Fig. 5] Fig. 5 is a plan view of the second non-feeding radiation element 5 when the second non-feeding radiation element 5 is expanded based on a peripheral face of the second non-feeding radiation element 5.

[Fig. 6] Fig. 6 is a graph showing experiment results of the resonance characteristics of the antenna according to the first

embodiment of the present invention.

[Fig. 7] Fig. 7 is a graph showing each resonant state of the antenna.

[Fig. 8] Fig. 8 is a graph showing a magnified fundamental-wave portion.

[Fig. 9] Fig. 9 is a graph showing a magnified harmonic-wave portion.

[Fig. 10] Fig. 10 is a perspective view of an antenna according to a second embodiment of the present invention.

[Fig. 11] Fig. 11 is an equivalent circuit diagram showing the antenna according to the second embodiment of the present invention.

[Fig. 12] Fig. 12 is a perspective view of an antenna according to a third embodiment of the present invention.

[Fig. 13] Fig. 13 is a perspective view showing a fitting structure in an antenna according to a fourth embodiment of the present invention.

[Fig. 14] Fig. 14 is a perspective view showing another example of the fitting structure in the antenna according to the fourth embodiment.

[Fig. 15] Fig. 15 is an illustration showing en example of a schematic structure of a known inverted-F antenna.

[Fig. 16] Fig. 16 is an illustration showing an example of a known cellular phone unit including a first antenna element and a second antenna element at an end in a longitudinal direction.

[Fig. 17] Fig. 17 is an illustration showing a triple-resonance

surface-mount antenna main unit.

[Fig. 18] Fig. 18 is an illustration showing an antenna device in which a ground opening is formed in a ground electrode on which a surface-mount antenna main unit is provided.

Best Mode for Carrying Out the Invention

Best mode for the present invention is described with reference to the drawings.

Embodiment 1

Fig. 1 is a plan view showing an antenna according to a first embodiment of the present invention, Fig. 2 is a side view of the antenna according to the first embodiment, and Fig. 3 is a perspective view of the antenna according to the first embodiment.

As shown in Fig. 1, an antenna 1 according to this embodiment includes a ground electrode 2, a feeding radiation element 3, a first non-feeding radiation element 4, and a second non-feeding radiation element 5.

The ground electrode 2 is formed of a conductor that has a substantially rectangular outer shape when viewed in plan and that is made of sheet metal or metallic foil and is installed on a substrate 6, as shown in Fig. 2. The ground electrode 2 functions as a so-called ground substrate.

As shown in Fig. 1, the feeding radiation element 3 is a generally flat surface mount element of a rectangular parallelepiped shape. The feeding radiation element 3 is disposed on the ground electrode 2 such that one side (referred to as a connection side 9) is disposed substantially parallel to

and in the vicinity of a predetermined side 2a of the ground electrode 2.

As shown in Fig. 3, the feeding radiation element 3 includes a dielectric base member 7 and a radiation electrode 8. The dielectric base member 7 is formed by, for example, injection molding of a dielectric material. The radiation electrode 8 is made of a conductor, such as sheet metal or metallic foil, provided on the surface of the dielectric base member 7. The radiation electrode 8 is an antenna pattern of about one turn and includes a slit 8a, as shown in Fig. 1. Thus, the face of the radiation electrode 8 is parallel to the face of the ground electrode 2. The radiation electrode 8 is an electromagnetic wave radiation electrode that is loaded with a dielectric substance due to the dielectric base member 7. The radiation electrode 8 is connected to an external signal supply source or the like, which is not shown, and actively radiates radio waves. That is, feeding means, which is not shown, directly supplies power to the radiation electrode 8.

The first non-feeding radiation element 4 is a generally flat element of a rectangular parallelepiped shape. The first non-feeding radiation element 4 is disposed next to the feeding radiation element 3 on the ground electrode 2 such that one side (referred to as a connection side 11) is disposed substantially parallel to and in the vicinity of the side 2a of the ground electrode 2.

As shown in Figs. 2 and 3, the first non-feeding radiation

element 4 includes the dielectric base member 7 and a radiation electrode 10. The dielectric base member 7 is shared with the feeding radiation element 3. Thus, similarly to the radiation electrode 8, the face of the radiation electrode 10 is parallel to the face of the ground electrode 2. The radiation electrode 10 is disposed adjacent to the radiation electrode 8 with a predetermined gap therebetween on the dielectric base member 7 and is connected to the ground electrode 2. Similar to the radiation electrode 8 of the feeding radiation element 3, the radiation electrode 10 is an antenna pattern of about one turn and includes a slit 10a, as shown in Fig. 1.

The second non-feeding radiation element 5 is a passive antenna element having a generally flat and elongated shape. The second non-feeding radiation element 5 includes a dielectric base member 12 and a radiation electrode 13. The second non-feeding radiation element 5 is disposed adjacent to both the feeding radiation element 3 and the first non-feeding radiation element 4.

That is, as shown in Fig. 3, a connection side 15 of the second non-feeding radiation element 5 is attached in parallel to both the connection side 9 of the feeding radiation element 3 and the connection side 11 of the first non-feeding radiation element 4, and almost the entire second non-feeding radiation element 5 projects outside the side 2a of the ground electrode 2.

Fig. 4 is a perspective view of the second non-feeding radiation element 5, and Fig. 5 is a plan view of the second non-feeding radiation element 5 when the second non-feeding radiation

element 5 is expanded based on a circumference face of the second non-feeding radiation element 5.

As shown in Fig. 3, although the dielectric base member 12 is independent of the dielectric base member 7 and has a planar shape that is different from the dielectric base member 7, the dielectric base member 12 has the same thickness as the dielectric base member 7. The dielectric base member 12 is a rectangular parallelepiped and has longer sides in a direction of the side 2a of the ground electrode 2. The radiation electrode 13 is provided on the surface of the dielectric base member 12. Thus, similarly to the radiation electrodes 8 and 10, the face of the radiation electrode 13 is parallel to the face of the ground electrode 2.

More specifically, as shown in Fig. 4, an end 13a of the radiation electrode 13 is disposed on the connection side 15 of the dielectric base member 12. The radiation electrode 13 extends from the end 13a to a top face 12b of the dielectric base member 12, and loops along a periphery of the top face 12b. Then, the radiation electrode 13 returns to a left side in the drawing of the connection side 15. That is, as shown in Fig. 5, the radiation electrode 13 is formed on the dielectric base member 12 such that both ends 13a and 13c of the radiation electrode 13 are disposed on the connection side 15 of the dielectric base member 12 and a loop portion 13b is disposed on the top face 12b. In addition, as shown in Fig. 3, when the second non-feeding radiation element 5 is attached to the feeding radiation element

3 and the first non-feeding radiation element 4, the end 13a of the radiation electrode 13 is connected at a central position 2b of the side 2a of the ground electrode 2.

As described above, the feeding radiation element 3 and the first non-feeding radiation element 4 function as an integrated surface-mount element including the radiation electrode 8 and the radiation electrode 10 that are disposed adjacent to each other with a predetermined gap therebetween on the dielectric base member 7. In addition, the second non-feeding radiation element 5 is formed by disposing the radiation electrode 13 on the dielectric base member 12, which is independent of the dielectric base member 7. The second non-feeding radiation element 5 is an independent electrode element, separated from the feeding radiation element 3 and the first non-feeding radiation element 4. Thus, after the feeding radiation element 3 and the first non-feeding radiation element 4 are provided on the ground electrode 2, the second non-feeding radiation element 5 can be provided by attaching the second non-feeding radiation element 5 to the connection sides 9 and 11. Accordingly, the face of the radiation electrode 13 is parallel to the face of the ground electrode 2.

In addition, the feeding radiation element 3 and the first non-feeding radiation element 4 can be formed by disposing the radiation electrode 8 and the radiation electrode 10 in advance in predetermined positions within a die (not shown) for injection molding and by performing insert molding using, as a forming

material of the dielectric base member 7, a dielectric material with thermoplastic resin. Alternatively, the feeding radiation element 3 and the first non-feeding radiation element 4 may be formed by performing outsert molding.

In addition, similarly, the second non-feeding radiation element 5 can be formed by disposing the radiation electrode 13 in advance in a predetermined position within a die for injection molding and by performing insert molding using, as a forming material of the dielectric base member 12, a dielectric material with thermoplastic resin. Alternatively, the second non-feeding radiation element 5 may be formed by performing outsert molding.

Operations and advantages of the antenna 1 according to this embodiment are described next.

Fig. 6 is a graph showing experimental results when the resonance characteristics of a case where a second non-feeding radiation element is installed in the antenna according to this embodiment and the resonance characteristics of a case where the second non-feeding radiation element is removed from the antenna are compared with each other.

When, in the antenna 1 shown in Fig. 1, a signal is supplied from an external signal supply source or the like to the radiation electrode 8, the radiation electrode 8 actively radiates electromagnetic waves. Due to the electromagnetic waves, the radiation electrode 10 and the radiation electrode 13 passively resonate. Thus, the radiation electrode 8, the radiation electrode 10, and the radiation electrode 13 produce a

triple resonance.

Here, the first non-feeding radiation element 4 is disposed on the ground electrode 2, and the second non-feeding radiation element 5 is disposed outside the ground electrode 2. In addition, the planar shape and the overall size are different between the first non-feeding radiation element 4 and the second non-feeding radiation element 5. Thus, the first non-feeding radiation element 4 and the second non-feeding radiation element 5 have resonant frequency bands that are obviously different from each other. In addition, each of the radiation electrode 8, the radiation electrode 10, and the radiation electrode 13 is loaded with a dielectric substance. Thus, each of the radiation electrode 8, the radiation electrode 10, and the radiation electrode 13 resonates in a desired resonant frequency band.

In order to confirm the above-mentioned points, an experiment is performed. As shown by a curve A in Fig. 6, a triple resonance including clear peaks at resonant frequencies in three frequency bands 41, 42, and 43, which are clearly different from each other, is achieved.

The experiment will be described more specifically.

In this experiment, the resonance characteristics of a case where the second non-feeding radiation element 5 is installed in the antenna 1 and the resonance characteristics of a case where the second non-feeding radiation element 5 is removed from the antenna 1 are compared with each other.

More specifically, the dimensions of the ground electrode 2

are set such that the width W is 40 mm and the length L is 165 mm. In addition, the dimensions of the dielectric base member 7 (see Fig. 2 or Fig. 3) (that is, the dimensions are substantially equal to the total of the dimensions of the feeding radiation element 3 and the dimensions of the first non-feeding radiation element 4) are set such that the width b is 26 mm, the length a is 23 mm, and the thickness D is 3 mm. In addition, the dimensions of the dielectric base member 12 (that is, the dimensions are substantially equal to the dimensions of the second non-feeding radiation element) are set such that the length w is 32 mm, the width c is 5 mm, and the thickness D is 3 mm. The dielectric base member 7 and the dielectric base member 12 are made of dielectric materials having a dielectric constant of 6.4.

Under such conditions, the resonant experiment is performed using the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5. As shown by the curve A in Fig. 6, a triple resonance with an excellent matching including three different resonant frequency bands, that is, a first resonant frequency band 41 in which the peak exists at about 825 MHz, a second resonant frequency band 42 in which the peak exists at about 890 MHz, and a third resonant frequency band 43 in which the peak exists at about 960 MHz is observed. That is, in the antenna 1 according to this embodiment, in a fundamental wave, a multiple resonance with an excellent matching can be achieved over a wide band from about 800 MHz to

1000 MHz including the first resonant frequency band 41, the second resonant frequency band 42, and the third resonant frequency band 43.

In contrast, the experiment in which the feeding radiation element 3 and the first non-feeding radiation element 4 produce a resonance when the second non-feeding radiation element 5 is removed is performed. In this case, as shown by a curve B in Fig. 6, a resonance including the clear peak is generated in the third resonant frequency band 43. However, the resonance in the first resonant frequency band 41 is almost completely lost, and the sharpness of the resonance peak in the second resonant frequency band 42 is significantly reduced.

In accordance with the above-mentioned experiment results, the occurrence of a multiple resonance with an excellent matching including clear peaks in the first resonance frequency bad 41, the second resonance frequency band 42, and the third resonant frequency band 43 is observed when the second non-feeding radiation element 5 of the antenna 1 is disposed outside the ground electrode 2.

Here, the fact that an antenna using the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5 is capable of producing a multiple resonance over a wide band is considered.

Fig. 7 is a graph showing each resonance in the antenna, Fig. 8 is a graph in which a fundamental-wave portion is magnified, and Fig. 9 is a graph in which a harmonic-wave portion is

magnified.

As a first comparative example, an antenna main unit from which the first non-feeding radiation element 4 is removed, that is, the feeding radiation element 3 disposed on the ground electrode 2 produces a single resonance, and matching with the second non-feeding radiation element 5 disposed outside the ground electrode 2 is achieved. Accordingly, a multiple resonance in a fundamental wave is achieved. In this case, as shown by a curve S02 represented by a two-dot chain line in a fundamental-wave portion B in Figs. 7 and 8, a multiple resonance can be achieved in a fundamental wave. However, as shown by a curve S02 in a harmonic-wave portion H in Figs. 8 and 9, a satisfactory resonance cannot be achieved in a harmonic wave.

As a second comparative example, the feeding radiation element 3 and the first non-feeding radiation element 4 that are disposed on the ground produce a multiple resonance (double resonance). In this case, as shown by a curve S01 represented by a dotted line in a fundamental-wave portion B and a harmonic-wave portion H in Figs. 7 to 9, an excellent multiple resonance is achieved in a fundamental wave and a harmonic wave. However, since both the feeding radiation element 3 and the first non-feeding radiation element 4 are disposed on the ground electrode 2, the Q value of each of two resonances constituting the double resonance is high. Thus, there is a limit to an increase in bandwidth for such a multiple resonance.

In accordance with the results of the first and second

comparison examples, the fact that, for a single resonance, the use of the second non-feeding radiation element 5 disposed outside the ground electrode 2 increases the bandwidth although a problem occurs in a harmonic wave and that, for a multiple resonance caused by the feeding radiation element 3 and the first non-feeding radiation element 4 that are disposed on the ground electrode 2, an excellent multiple resonance can be achieved in a fundamental wave and a harmonic wave although a problem occurs in the width of the bandwidth is found. Thus, by combining the results of the first and second comparative examples and by forming an antenna of the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5, it is considered that advantages in respective cases are added and that drawbacks can be overcome.

Thus, the feeding radiation element 3 and the first non-feeding radiation element 4 are disposed on the ground electrode 2, the second non-feeding radiation element 5 is disposed outside the ground electrode 2, and the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5 produce a triple resonance. In this case, as shown by a curve S012 represented by a solid line in the fundamental-wave portion B and the harmonic-wave portion H in Figs. 7 to 9, an excellent triple resonance can be achieved in a fundamental wave and a harmonic wave, and a wider bandwidth can be achieved. The antenna according to this embodiment is created under such consideration. Thus, the use of the antenna according

to this embodiment realizes a communication apparatus supported by all the specifications of GSM 850/900/18001900/UMTS (a bandwidth between 824 MHz and 960 MHz and a bandwidth between 1710 MHz and 2170 MHz are used), CDMA 800 (a bandwidth between 832 MHz and 925 MHz is used), and PDC 800 (a bandwidth between 810 MHz and 960 MHz is used), as shown by the curve S012 in Fig. 7.

In the antenna 1 according to this embodiment, as shown in Figs. 2 and 3, each of the radiation electrode 8, the radiation electrode 10, and the radiation electrode 13 is loaded with a dielectric substance, and an excellent multiple resonance can be produced. Thus, even if the thickness of each of the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5 is not set to be equal to the thickness (the distance from a ground plate to an antenna plate that floats above the ground plate) in, for example, a generally known inverted-F antenna, an increase in bandwidth can be achieved. As a result, a reduction in the thickness of the entire antenna 1 can be achieved. For the antenna 1 according to this embodiment, the thickness D of each of the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5 is about 3 mm. Even if the thickness of the ground electrode 2 and the substrate 6 is added, a reduction in the thickness of the entire antenna 1 can be achieved.

In addition, for example, for an inverted-F antenna that is

not loaded with a dielectric substance, since a large electric field leaks out toward the head of a user, when the user brings his or her head closer to the antenna, communication performance may be significantly deteriorated. However, in the antenna 1, since each of the radiation electrode 8, the radiation electrode 10, and the radiation electrode 13 is loaded with a dielectric substance, for example, leakage of an electric field from the side 2a of the ground electrode 2 to the head of the user can be suppressed due to the dielectric base members 7 and 12.

In addition, since the radiation electrode 13 is connected at the central position 2b of the side 2a of the ground electrode 2, induced currents Ia and Ib flow in opposite directions from each other along the side 2a, as shown in Fig. 3. Thus, the induced currents Ia and Ib cancel each other. Therefore, when the user brings his or her head closer to the antenna, an electric field that leaks out from peripheral four sides of the ground electrode 2 to the head can be reduced or prevented.

In addition, since the second non-feeding radiation element 5 is loaded with a dielectric substance due to the dielectric base member 12, the external planar dimensions of the second non-feeding radiation element 5 can be reduced. Thus, even if the second non-feeding radiation element 5 projects outside the ground electrode 2, the size of the projection can be reduced. In the antenna 1 according to this embodiment, the external shape of the second non-feeding radiation element 5 is flat and elongated, and the size of the projection is set to 5 mm or less.

As a result, miniaturization of the entire antenna 1 can be achieved.

In addition, the second non-feeding radiation element 5 is disposed such that the length in the longitudinal direction of the second non-feeding radiation element 5 falls within the length of the side 2a of the ground electrode 2, and a multiple resonance is produced. Thus, a ground wire, an antenna element, and the like suggested in known technologies are not necessarily provided at a corner of a ground plate (ground electrode 2). Therefore, in the antenna 1 according to this embodiment, the shape of four corners (corner portions) of the ground electrode 2 is not restricted due to the installation of the ground wire, and the flexibility in designing the entire shape and the flexibility in designing for mounting when a CCD image pickup element (not shown) or the like is provided on the substrate 6 can be increased.

As described above, in the antenna 1 according to this embodiment, a reduction in the thickness and miniaturization of the overall size can be achieved and a further increase in bandwidth can be achieved.

Embodiment 2

Fig. 10 is a perspective view of an antenna according to a second embodiment of the present invention, and Fig. 11 is an equivalent circuit diagram showing the electric circuit structure of the antenna according to the second embodiment. In the second embodiment, the same component parts as in the first embodiment

are referred to with the same reference numerals.

In the antenna according to this embodiment, the feeding radiation element 3 and the first non-feeding radiation element 4 are disposed on the ground electrode 2 such that the connection sides 9 and 11 are offset so as to be disposed slightly inward from the side 2a of the ground electrode 2, as shown in Fig. 10. A chip capacitor 22 and chip coils (chip inductors) 23 and 24 are provided in a certain space S on the ground electrode 2 generated by the offset.

The chip capacitor 22 is inserted between a connection wire 25 connected to the radiation electrode 10 and the ground electrode 2. The chip coil 23 is inserted between a connection wire 26 connected to the radiation electrode 8 and the ground electrode 2. The chip coil 24 is inserted between the end 13a of the radiation electrode 13 and the ground electrode 2. Thus, the antenna 21 according to this embodiment has a structure shown in Fig. 11, in terms of an equivalent circuit.

That is, since the chip coil 23 is connected to the radiation electrode 8, the radiation electrode 8 is capable of achieving a desired matching for resonance characteristics due to the inductance of the chip coil 23. In addition, since the chip capacitor 22 is connected to the radiation electrode 10 and since the chip coil 24 is connected to the radiation electrode 13, a desired matching can be achieved for respective resonance characteristics.

With the arrangement according to this embodiment, desired

resonance characteristics for the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5 can be achieved easily and accurately by changing the characteristics of the chip capacitor 22, the chip coil 23, and the chip coil 24 without changing the shape and dimensions of the radiation electrode 8, the radiation electrode 10, and the radiation electrode 13 or without changing the material or the like of the dielectric base members 7 and 12.

Since the other structural features, operations, and advantages are similar to those in the first embodiment, descriptions thereof are omitted here.

Embodiment 3

Fig. 12 is a perspective view of an antenna according to a third embodiment of the present invention. In the third embodiment, the same component parts as in the first embodiment are referred to with the same reference numerals.

In the antenna according to this embodiment, the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5 are integrated together to form a single surface-mount antenna element 32, as shown in Fig. 12.

That is, the surface-mount antenna element 32 is formed by disposing the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5 on a single dielectric base member 7'.

The surface-mount antenna element 32 is provided on the

substrate 6 such that almost the entire second non-feeding radiation element 5 projects from the side 2a and such that the feeding radiation element 3 and the first non-feeding radiation element 4 are disposed on the ground electrode 2.

As described above, since the feeding radiation element 3, the first non-feeding radiation element 4, and the second non-feeding radiation element 5 are integrated together as the surface-mount antenna element 32, mounting on the substrate 6 (the ground electrode 2) can be performed easily.

Since the other structural features, operations, and advantages are similar to those in the first embodiment, the descriptions thereof are omitted here.

Embodiment 4

Fig. 13 is a perspective view showing a fitting structure of an antenna according to a fourth embodiment of the present invention. In the fourth embodiment, the same component parts as in the first embodiment are referred to with the same reference numerals.

As shown in Fig. 13, in this embodiment, fitting recesses 41a and 41b are provided in the feeding radiation element 3 and the first non-feeding radiation element 4, and fitting protrusions 42a and 42b are provided on the second non-feeding radiation element 5. That is, a fitting structure 40 includes the fitting recesses 41a and 41b and the fitting protrusions 42a and 42b.

More specifically, the fitting recesses 41a and 41b are

provided in the connection sides 9 and 11 of the dielectric base member 7, and the fitting protrusions 42a and 42b are provided on the connection side 15 of the second non-feeding radiation element 5. Thus, by fitting the fitting protrusions 42a and 42b into the fitting recesses 41a and 41b, the second non-feeding radiation element 5 can be connected at predetermined positions of the feeding radiation element 3 and the first non-feeding radiation element 4 in predetermined attitude.

Here, it is preferable that the fitting shape of the fitting recess 41a and the fitting protrusion 42a be different from the fitting shape of the fitting recess 41b and the fitting protrusion 42b. Thus, each of a connection state between the second non-feeding radiation element 5 and the feeding radiation element 3 and a connection state between the second non-feeding radiation element 5 and the first non-feeding radiation element 4 is set uniquely. Thus, for example, since the fitting recess 41a does not fit the fitting protrusion 42b, a situation in which the second non-feeding radiation element 5 is connected such that left and right are reversed can be avoided.

In addition, another fitting structure is possible, as shown in Fig. 14. That is, the fitting structure may include the fitting protrusions 42a and 42b including stop clicks 43a and 43b and fitting recesses 44a and 44b that are engaged with the stop clicks 43a and 43b.

Since the other structural features, operations, and advantages are similar to those in the first embodiment, the

descriptions thereof are omitted here.

The antenna according to each of the foregoing embodiments is suitably usable as an antenna contained in a portable radio communication apparatus, such as a cellular phone unit, for which a reduction in the thickness and miniaturization are required and for which a further increase in bandwidth is required.

The present invention is not limited to each of the foregoing embodiments, and various changes and modifications can be made to the present invention without departing from the gist of the present invention.

For example, in each of the foregoing embodiments, the radiation electrodes 8, 10, and 13 of the feeding radiation element 3 and the first and second non-feeding radiation elements 4 and 5 are formed on the surface of the dielectric base members 7 and 12. However, the radiation electrodes 8, 10, and 13 may be formed inside (within) the dielectric base members 7 and 12 such that the radiation electrodes 8, 10, and 13 are parallel to the ground electrode 2.

In addition, in each of the foregoing embodiments, the external shape of each of the feeding radiation element 3 and the first and second non-feeding radiation elements 4 and 5 is set to be a rectangular parallelepiped. However, the external shape is not limited to this. Any shape can be adopted as long as the external shape is three dimensional, such as a polygonal prism or a circular cylinder.

In addition, in each of the foregoing embodiments, feeding

means directly supplies power to the radiation electrode 8. However, feeding means that is capable of supplying power to the radiation electrode 8 without contact by electromagnetic coupling may be used.